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Concussion Awareness and Educational Outreach Through a Website and Mobile Application

Daniel J. Brogan
Ursinus College, dabrogan@ursinus.edu

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By: Daniel Brogan

Mentor: Dr. Bish, Joel

Department: Neuroscience

Abstract

In recent years concussions have become a more apparent problem in youth and adolescent sports. 1 in 5 high school students will sustain a concussion during the season. Due to medical and scientific advances, the diagnosis of concussions is becoming much simpler with key markers that are signs for an injury, although biomarkers for concussions remain to be ambiguous. Symptoms for concussions are necessary to track in order for an athlete to properly report their recovery to a physician. Doctors primarily rely on a patient's report of their symptoms to evaluate the total effect of the injury, recovery times are often misdiagnosed. Ursinus College- Concussion Outreach Group has been created so that concussion awareness can be raised. No methods have been found to completely prevent a concussion, so educational outreach is the first step. The group has decided to utilize a website and mobile application in order to promote safe techniques of play, along with awareness of how complex and misunderstood concussions are. In order to have a better diagnosis of a concussion it is important to completely monitor symptoms, which is possible using a mobile application. The website will serve as an information database, anonymous blog for sharing experiences, and will contain profile with data entered into the application. The site will provide full details on the dangers of concussions, as well as an "Ask the Expert" section for personal questions. It is not expected that this project will ultimately stop concussions from occurring. Granting adolescents the knowledge of the dangers that exist with concussions may cause an overall change in the attitudes attributed with concussions, hopefully so that concussions are not so under diagnosed. The effort behind making the website and mobile application is motivated by the need to promote responsible play in sports, educate everyone involved with the athlete why concussions are so serious, help

prevent premature return to play or academia, explain the risks behind playing certain sports, and encourage interest in future findings related to concussions.

Introduction

Mild Traumatic Brain Injuries (mTBI), concussions included, are becoming one of, if not already, the most common injury amongst all contact sports. The CDC has stated that in the last 10 years the amount of reported concussions in overall has doubled with a 200% increase in concussions of adolescents ages 14-19. Impact injuries to the brain can lead to long-term neurological deficits. In fact, data suggest persistent neurophysiological deficits that are present at least 6 months following a concussion (Baillargeon, A et al. 2011). High contact sports lead to an increased risk of receiving a concussion with no full proof solution for avoiding the injury. Even when techniques for hitting in football are perfected, the risk of receiving a concussive blow is high. The rising concern about concussions has led to the understandings that not only are concussive blows dangerous, but even repetitive sub-concussive hits may inevitably imply neurological problems. It is likely that damage to the frontal lobe resulting from a concussion may lead to deficits in impulse control in behavior, which may have links to higher risk of sustaining another concussion.

Multiple concussive blows can be detrimental to an adolescent. At the moment the consequences of returning an athlete to play too soon following a concussion are now beginning to be understood (May, K. H. et al 2014). Adolescents are still maturing, both physically and neurologically, and often still lack fully developed frontal lobes, which is functionally responsible for social inhibition and impulse control. Concussions consequentially have the ability to affect the development of an adolescent. Following one concussion there is a significant risk for a second concussion whose compounding effects can be detrimental to the

adolescent athlete (May, K. H. et al 2014). Successive concussions often lead to post-concussion syndrome, where typical concussion symptoms persist from either a month to possibly lasting years following the injury. One head injury can impact an adolescent's academic, social, and physical life significantly; multiple injuries can severely alter an adolescent's life in all three aspects. Premature return to play may be a result from poor monitoring of recovery or under diagnosing head injuries.

Concussions and the awareness of the injury are rising exponentially, yet it is still important not only to raise awareness but to make sure that there is a scientific culture shift. Adolescents throughout the world participate in fast-paced, high-contact sports that put them at risk for receiving an mTBI, repetitive blows to the head, or severe impacts. Adolescents are the least researched group of humans in terms of concussions and other traumatic brain injuries. The consequences that follow sustaining concussive and multiple sub-concussive hits in adolescence are not fully understood as of now. However, many researchers hypothesize that brain injury early in life can have long-term effects, whether it be one or multiple.

There is a real need to reach out and educate athletes, parents of athletes, coaches, and athletic directors about proper sports techniques that can help to limit the risk of receiving a concussion across all sports. These individuals must also become aware of how threatening concussions can be and why they should not be taken lightly. Playing hard is a great thing to do, but playing injured never turns out for the better. At Ursinus College a recent study has led to the hypothesis that it only takes one concussion to possibly alter an athlete's ability to control his impulsivity. These are based on findings using the Erikson & Flanker and Color Stroop Tests. Through this discovery the Ursinus College- Concussion Outreach Group (UC-COG) was created for the means of spreading awareness and educating individuals on the potential dangers

of concussions. A multi-media project is ideally the best catalyst for helping spread the word. The mobile application and website are being created to serve individuals been diagnosed with concussions, people whose lives have been effected by their or someone else's concussion, and others interested in the topic of the site.

One of the hardest things that an individual will face when recovering from a concussion is being able to track and recall the symptoms they experience following a concussion. [A concussion] is defined as a complex, pathophysiological process, affecting the brain, induced by traumatic biomechanical forces to the head, in the form of a blow and/or subjection to acceleration/deceleration forces that may or may not involve loss of consciousness (Stewart, G. W. et al 2012). Since concussions are such complex injuries and its mystery still being unveiled, finding an appropriate treatment for everyone has been quite arduous, especially because no one concussion is the same as another. Therefore not every person will experience the same symptoms following a mild traumatic brain injury. A recent international poll conducted by *Time magazine* found that 84% of people worldwide could not go a single day without their cell phones and 20% check their phone every 10min (Hung, M et al. 2013). There is a clear need to take advantage of the high rates of mobile use in America by implementing a mobile application that can provide symptom tracking and more for concussed individuals. An application can replace the need for a patient to remember and self-report symptoms to a physician, which can ultimately help diagnose a concussed individual's proper recovery time, along with helping to keep track if that time needs to be extended.

Resolving an athlete's symptoms, which are usually behavioral, following a concussive injury, is currently the main focus of recovery, due to a lack of proven biological markers for injury. The majority of concussion symptoms resolve within 10 days to two weeks (May, K. H.

et al. 2014) and this is about the standard recovery time for concussion symptoms for humans of all ages. The problem with this is that this standard of recovery fits adults, but not adolescents. Adults have fully developed brains and thus are less likely to be vulnerable to degenerative brain damage resulting from a successive injury. It is important to note that those who manage a younger athlete with a concussion should be prepared to extend the recovery timeline (May, K. H. et al. 2014). Adolescents may experience much more physiological changes in the brain when a concussion is received. With an adolescent's non-fully developed brain there is high risk of long-term injuries. Due to their hypothesized extended recovery time, successive concussions may occur at longer time intervals in adolescents. Using a mobile application that can keep track of all symptoms and experiences, underestimating recovery time can easily be avoided, which lowers the risk of receiving a secondary mTBI.

Proper treatment of a concussion remains to be solved and the topic is highly examined and discussed. As of now, there is evidence suggesting that there are strong ionic shifts in the brain at the time of impact. Studies suggest that impact trauma produces a transient membrane depolarization associated with a pronounced cellular release of K + and a massive Ca2 + entry into the intracellular compartment (Nilsson, P et al 1993). As a result, local neurons experience apoptosis due to their inability to function. This ionic fluctuation is possibly the largest contributor to cell death following an mTBI. As this ionic shift occurs, human biology attempts to repair this damage by using up large amounts of ATP, in an effort to maintain the same level of function. However, the death of the neurons restricts the amount of blood reaching the impacted area of the brain, which implies both oxygen and glucose cannot reach the nearby cells expending all of their energy. This imbalance in energy supply and demand is often associated with the typical headache that many concussed individual's experience. Acute impairments of

cellular metabolism have described problems in both glycolytic and oxidative pathways (Giza, C. C. and Hovda, D. A. 2015). This cannot currently serve as a biomarker, since there are no studies done in humans at the time of impact. However, this may be a possible stepping stone in diagnosing concussions. If the brain is lacking energy, then fatigue and a headache may be the most obvious symptoms. Yet there is still much to be examined with this research.

On top of an energy crisis, the brain becomes inflamed; attempting to resolve and heal the injury naturally. Many individuals will try to compensate with the inflammation by taking an anti-inflammatory drug. It has been suggested that neuroinflammation contributes to the neuroprotective regenerating efforts of the brain and in its absence the cumulative damage is increased following injury (Patterson, Z. R. and Holahan, M. R. 2012). Even if it is theoretically possible to help heal a concussion using anti-inflammatory drugs, the absence of valid data that proves if it helps or harms the brain is too significant to ignore. It is rational to abstain from using such drugs unless it is definitely recommended by a physician. Other pharmaceutical treatments have been tested, including ADHD medication, opiates, etc. At present, there is no evidence-based pharmacological treatment for concussions in humans (Patterson, Z. R. and Holahan, M. R. 2012). It is practical to find a solution to concussions biologically in the future, but current understandings of the injury have not led to an answer. Biological markers that can inform us that a traumatic brain injury has occurred will be the most appropriate evidence to promote pharmacological treatment of concussions.

The best-practice recommendation for concussion management is rest until all symptoms resolve (Carson, J. D. et al 2014). Afterwards a patient will gradually return to physical and cognitive activity while being monitored for any signs of symptom return. From there on the doctors will monitor symptoms and once the symptoms disappear, a patient can be cleared to

return to their typical lifestyle. The problem is not all symptoms are the same and not every athlete will have the same exact symptoms. [It is] recommend that the professional who coordinates the athlete's post-concussion healthcare should focus efforts upon a comprehensive assessment and tailored treatment plan specific to the athlete's post-concussive symptoms (Stewart, G. W. et al 2012). Adolescents seem to have to face more obstacles following a concussion considering the fact that they must return to academics and social life, along with returning to play. The guidelines for return to play following a concussion continuously adjust to scientific evidence, but academic guidelines remain to be properly enforced. Students often have to meet educational requirements without accommodation for cognitive impairment (Stewart, G. W. et al 2012). States are beginning to change the way concussed students are treated with regards to education, due to cognitive stress that can lead to exacerbation of symptoms. As changes to academic curriculums to accommodate for cognitive impairments begin to arise, students will have to be conscious of the changes to their everyday academic lives. For example, students are supposed to be given extensions on all school work when an mTBI occurs. Students will experience trouble remembering their own symptoms, let alone keeping a watchful eye on schoolwork due dates following a concussion. Tracking the due dates of their academic affairs using a mobile application provides a feasible method to replace the self-reliance on impaired memory.

Post concussive symptoms resulting from head trauma can have a negatively influence on a person’s life. It is probable that a person who has suffered a mild to moderate traumatic brain injury will experience symptoms past the expected recovery time period. Some programs have shown to be effective in the reduction of post-concussive symptoms, which ultimately will help any individual return to their typical lifestyle. Cognitive Symptom Management and

Rehabilitation Treatment (CogSMART) is a computer program created to help veterans, who have received a traumatic brain injury, return to the job market while experiencing less post-concussive symptoms. Results suggest that adding CogSMART to supported employment may improve post concussive symptoms and prospective memory (Twamley, E. W. et al. 2014). The program provides methods for readjusting to the social life of working, as well. Programs focusing on the appropriate cognitive recovery following traumatic brain injury can serve as useful guides for how to help adolescent students return to education. Some programs already demonstrate their effectiveness in guiding adults back to normal everyday life, but this does not necessarily imply that they will be efficient in alleviating symptoms in adolescents.

To understand why it is so imperative to monitor returning to play (RTP) and returning to learning (RTL) in adolescents, the severe consequences that result from mTBI and repetitive mTBIs must be accounted for. Recent studies have started to give a glimpse of evidence suggesting that concussions may have a significant impact on impulsivity. Properly functioning impulse control in humans reduces the likelihood of risky behavior. When an athlete plays a sport less cautiously they are increasing their chance of injury. Impulse control problems seem to persist even months following one single traumatic brain injury, implying that even months after injury an athlete may have riskier behavior when participating in a sport. Simply, if a person receives one concussion it can increase the chance of receiving a secondary concussion or another injury, even from a minor blow. The brain becomes vulnerable once injured, exactly how muscles bruise from impact and are then exposed to being injured again. Parents and adolescent athletes must become aware that it is highly reasonable to assume one head injury that leads to another; can potentially cause long-term cognitive complications if left unaddressed.

Predisposed factors can contribute to much more exaggerated symptoms and a prolonged recovery time following mTBI. A predisposition, for example, can be as simple as having a headache prior to injury. Some studies indicate the reporting of headache symptoms or a prior history of migraine as potential risk factors for prolonged recovery or more severe symptoms after concussion (Giza, C. C. and Hovda, D. A. 2015). ADHD remains to be a controversial medical disorder with concussions and other TBI. The cognitive symptoms of impaired attention and memory and the behavioral symptoms that arise after a concussion can mirror those of a patient with ADHD (White, R. D. et al 2014). If prior physiological or behavioral factors of an athlete are similar to symptoms following a concussion, it may be possible that they will experience exacerbated symptoms with an extended recovery. A study comparing children (5-15 years of age) with mild, moderate, and severe TBI showed that children with pre-injury ADHD had more significant and longer lasting symptoms of inattention and hyperactivity after TBI than controls (White, R. D. et al 2014). Children and adolescents diagnosed with ADHD are more likely to exhibit risky behaviors even while knowing the consequences which can follow. The risky behavior can translate over to sports where the athletes put themselves into a competitive setting that will include injury-prone situations.

Repetitive TBI, especially in cases where a concussion is diagnosed, often lead to neurodegenerative diseases and cognitive complications. Symptoms can recover relatively quickly following a TBI, but data suggest cognitive and behavioral recovery takes an excess amount of time. Electrophysiological data and neuropsychological assessments indicate that the functional disturbance takes 30–45 days to return to baseline level (Ling, H et al 2015). Actual concussive hits are not even the full concern for athletes when they engage in sports. These subtle neurobiological changes that can influence cognition may ultimately usher in the more

chronic effects of traumatic brain injury (Willeumier, K. et al 2012). Repetitive mTBIs over the career of the athlete (which may have been undiagnosed or unappreciated at the time of the injury) may result in the development of chronic traumatic encephalopathy (CTE) (Kimbler, D. E. et al 2013). The risk of CTE from heading the ball in soccer is increasingly recognized. Early CTE changes were reported in an amateur soccer player (Ling, H. et al 2015). Contact sports such as soccer, football, ice hockey, etc. who have their players exposed to repetitive impacts to the head increase the probability of players developing long-term neurological disorders. Boxers were the first group of athletes to be known to be ailed with neurophysiological deficiencies. The long term irreversible and progressive aftermath of TBI in boxers depicted as *punch drunk syndrome* was described almost a century ago and is now widely referred as CTE (Ling, H et al 2015). Now studies suggest that nearly all sports that expose players to repetitive head trauma may link to long-term neurodegenerative diseases. However, adolescents have not been studied as meticulously and there exists a lack of information on the exact dangers for adolescents relating to TBI. [Early diagnosis and medical intervention are of utmost importance] by data suggesting that high school athletes require longer recovery periods from concussion as compared with adults (Kimbler, D. E. et al 2013). In an effort to prevent long-term brain injuries from occurring within all sports, athletes of all levels of competition, parents, and coaches must be exposed to the knowledge of the dangers behind such injuries.

Websites can serve as places for people to go and get a hold of information about subjects of high importance. Concussions and all other TBIs are an undoubtedly momentous topic of interest. Using a website it is possible to reach out to the world and spread information about what the consequences of sustaining a concussion could be or why it is important for symptoms to be properly monitored, whatever question a person would have to ask about concussions.

Concussions are very complicated to treat and often require the availability of a team of professionals for the treatment process. In modern times it is somewhat difficult for an athlete to constantly be in contact with their rehabilitation team, even at times when they need an immediate answer. Implementing a section, for a concussion information website, devoted to communication to experts on concussions and concussion treatment can provide easy access information for anyone involved with helping treat an individual's concussion. An anonymous blog will also be included in the website to create a community of individuals who wish to share stories and experiences with dealing with concussions. The anonymity of the blog will service all individual's needs for privacy of their health information. Videos with professional athletes who have been diagnosed with long-term neurodegenerative disorders as a result of repetitive concussive and sub-concussive blows will be incorporated into the internet, along with links to other websites that hold and provide information relating to the topic of concussions. With regards to concussions, the purpose of the website is to provide information concerning all aspects of the injury, impart a way for users to communicate with experts of TBI, and educate everyone possible how perilous sports-related brain injuries can be, to not only an adult's, but an adolescent's brain.

Mobile applications are readily available in modern society and most citizens in developed countries at all times carry a mobile phone with them. Most mobile users check their phone frequently throughout the day, receiving alerts and reminders from multiple mobile applications. The development of an application devoted to concussion symptom tracking and management is in order. Athletes, and in the future, soldiers, can then receive reminders for recording, and then the information can be stored on the user's profile, which links to the website, later to be accessed by a physician. Self-report is the basis of how symptoms are tracked

by physicians now. Patients who sustain a concussion are to mentally track and memorize the symptoms they experience while they rest, and then later report their experience to their doctor. This is not such an easy task for an individual whose memory has been impaired. A mobile application can replace the need to memorize symptoms by providing questionnaires about the symptoms being experienced and the uploading the report to a database where the information can be retrieved. A calendar for doctor's appointments and academic due dates will be included on the application and will send reminders for when these appointments arrive. Applications that provide pharmaceutical treatment monitoring through mobile technologies have been studied. Mobile technology-based [ecological momentary intervention] can be effectively implemented as interventions for a variety of health behaviours and psychological and physical symptoms (Heron, K. E. and Smyth, J. M. 2010). Coincidentally, concussions seem to permit psychological and physical symptoms to result from the injury. Therefore, if people have used reminders and alerts to monitor anxiety, smoking cessation, weight loss, and more, then the ecological momentary interventions should evidently be successful in tracking and treating concussions. Tracking symptoms and recording symptom data through mobile application will be used following injury and will help to make the recovery of a concussed individual more accurate and successful.

Parents will be able to monitor the academic due dates and doctor's appointments of adolescents who have suffered some type of traumatic brain injury, assuming that responsibility lies with their guardians. Adolescents will still have access to this information, as well. Only the injured athlete's profile will be able to track symptoms and pull them up; guardians will not be able to access this feature. A shared profile between website and application will be necessary for when a concussed athlete goes to see his physician, the doctor can pull up his tracked

symptoms on the website profile page. With an accurate tracking of the symptoms the doctor will be able to properly establish a recovery time and anticipate a certain date for when to expect RTP and RTL. A multipurpose application for concussions can help future research understandings of the injury and mostly help to prevent further, more damaging, injury.

Proposed Methods

Reaching out to high schools is the current goal of the UC-COG. Networking to local schools around Ursinus College and giving presentations on concussion information and awareness. The presentation will also promote the website and application completed by the UC-COG, encouraging the students to use both technologies, especially if they are athletes who play a physical contact sport. The immature brain of an adolescent must be protected and educating adolescents about head injuries can help prevent serious damage.

When designing the website, we must secure the profiles of users and allow them to communicate anonymously over the site. With health record data attached to some user profiles, security is of high importance. New discoveries will be reported and updated onto the website home page, where new important posts and links will be available. Links to websites with information on traumatic brain injuries, such as the Center for Disease and Control, will be provided. Videos from professional athletes or other individuals whose lives have been changed by one or more traumatic brain injury will also be available for all users to view. Users and visitors of the concussion website must be exposed by enough information to become fully aware of what consequentially follows a concussion or other traumatic brain injury.

The application will have basic, easy-to-use layout for the symptom tracker, a design that will not cause any frustration or stress.

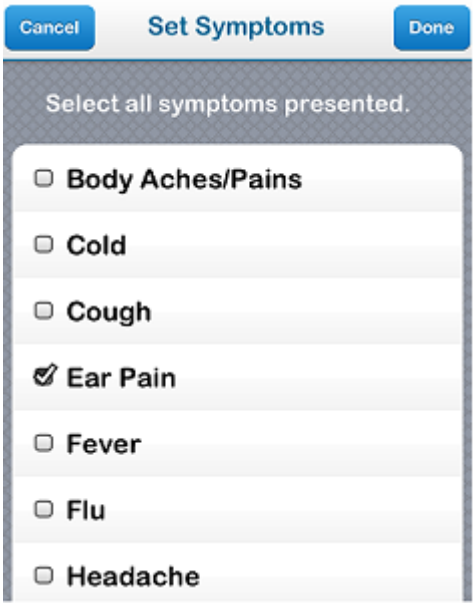

Figure 1. Here is an example of what the layout for the symptom tracker will look like. Simple questions and checklists are provided on a plain format. Note: the color scheme will be very different.

Above the figure does not demonstrate the actual color layout of the application. The widespread ionic flux described after FPI has often been described as 'spreading depression-like', and the original description of the spreading depression of Leao was in the context of migraine. There is considerable overlap of typical post-concussion symptoms with those commonly described in migraine (Giza, C. C. and Hovda, D. A. 2015). With migraines comes sensitivity to light and when exposed to light during a migraine an individual may experience extreme discomfort. Therefore the background lighting will be black with white lettering, which is easier on the eyes and less stressful for the brain.

Discussion

Concussions are a rising epidemic in America and many other nations throughout the world. The high participation rates of adolescents in sports represent a significant statistic that may be able to explain why the number of concussions being diagnosed each year is rising, or perhaps that cause comes from the increase in medical diagnostic tools for concussions.

Regardless becoming more aware of the injury that is inflicting athletes everywhere will increase the apparent need to address the issue and make the issue more obvious. Concussions and repetitive sub-concussive hits are highly likely to lead to neurodegenerative diseases in the long-term. These are injuries that cannot be ignored and the risk of neglecting such an injury can have detrimental effects on a person's life.

Formerly, it was believed that because adolescents are young and still developing, their neuroplasticity should allow them to recover much easier from head trauma than adults. But contrary to popular belief, adolescents are in fact much more vulnerable to serious functionality loss due to their underdeveloped brain. Regions that happen to be underdeveloped during adolescence (the frontal lobe) are regions that are likely to become impaired when an impact occurs. This is why impulse control deficits exist even 6 months following a single concussive injury, because the frontal lobe is responsible for inhibition of impulsivity. Other behavioral and psychological symptoms were shown to persist even over 2 months post injury, after typical concussion symptoms have subsided. Growing evidence suggests that adolescents require an elongated recovery time from a traumatic brain injury, implying that an adjustment to sports rules for return to play must be modified.

Further research into how long following an injury a person may exhibit cognitive problems may help to contribute to the answer of how long a person needs to recover from head injuries. If reports begin to show that functional symptoms of a concussion can last over 6 months post injury, results may begin to show that there is permanent damage even from one injury. Athletes who have sustained multiple head impact trauma are susceptible to exhibiting many different psychological and cognitive deficits. Repetitive impacts to an athlete's head also increase the likelihood of being diagnosed with CTE or dementia later on in life. Although this

injury seems very intimidating and very damaging, current research is progressing towards making sports safer and concussions avoidable. Untangling the connections between acute and chronic pathophysiology of concussion holds the promise for better prevention of repeated injury and mechanism-based therapies to interrupt the progression to persistent deficits or neurodegeneration (Giza, C. C. and Hovda, D. A. 2014).

Results concerning ADHD and its extreme over diagnosis may lead to contestable results concerning impulsivity. If patients are already impulsive, due to attention deficits, prior to a concussion, then their data will be unusable. ADHD is a very large variable and has links to being prone to injuries in athletics, including head trauma, just as receiving a single concussion increases the chances of receiving a successive concussion.

Conclusion

In order for concussions to become more manageable there needs to be a societal change for people's views on how much a concussion can impact an athlete's life, notably when they are students. It is now being discovered that cognitive impairments linger on longer than typical concussion symptoms, therefore there could be effects on education and social life following an injury. In typical mature adults, frontal lobes are completely developed and properly inhibit inappropriate behavior and thus reduce impulsivity. Adolescents do lack fully developed frontal lobes, causing a deception of unnoticed symptoms. Adolescents already have impulsive behavior in comparison to adults; it is a part of not being "mature". Therefore adolescents who sustain concussive blows may not behaviorally show the brain damage resulting from impact. With this knowledge parents, coaches, and athletic directors will have more concern for an athlete's mental health; thus being much more cautious with recovery times and treatment. Continuous impacts to a person's head, no matter what age, will probably not lead to very good results for that person's

mental health. Many athletes put their entire physical effort into play, holding nothing back and risking whatever it takes to win. Although, this determination is admirable, brain injuries, like any other injury, cannot be ignored. Raising awareness and providing information, whether it advises to be cautious or teaches proper playing techniques, is the primary concern of the UC-COG. With the information gathered UC-COG can start by branching out to surrounding Philadelphia areas, contacting high schools, and spreading awareness on all there is to know about concussions. Using a multi-media approach, adolescents will be easily attracted to the website and application. Treatment techniques for a concussion vary in many dimensions, but regardless of treatment method, the ability to monitor concussion recovery, while providing helpful information, through technology appears to be the most suitable method of receiving the most beneficial rehabilitation.

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